

Cotton production potential and water conservation impact using the regional irrigation demand model of northern Texas

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Abstract

Revised irrigation demands are calculated for the 21 northernmost counties in Texas, identified as Region A, using the TAMA (Texas A&M–Amarillo) agricultural water use demand estimation model. Year 2000 demands are presented using the existing mixture of crops, average evapotranspiration values and actual irrigation application practice values. Current demand values are expected to exceed the allowable water supply in several, intensively irrigated counties within the region. Thus, the alternative, lower water use crop of cotton is evaluated in terms of substitution potential for the presently produced, more intensive water use crop of corn. Although cotton has significant, differing production requirements in northern Texas, successful production has been documented within the region at the North Plains Research Field (NPRF) and average yield parameters are presented.

The water savings impact of converting percentages of county acreages from corn to cotton is reported and discussed. The water conservation impact to the Ogallala aquifer is calculated over the region's current 60-year planning horizon. The potential impact of recent ethanol demands is briefly discussed.

Background

Irrigation in the northern Texas High Plains is the largest water use sector and accounts for almost 90% of groundwater withdrawals from the Ogallala aquifer (Marek et al. 2000 and Amosson et al. 2005). The Ogallala aquifer level in this heavily irrigated region of Texas continues to decline as this portion of the aquifer has no appreciable rate of recharge.

In 1997, the establishment of 16 water management regions within Texas (Freese and Nichols 2001) was established by the Texas legislature. Each region was to assess and develop a feasible analysis of water management strategies that could be potentially implemented over the next 60 years per region, where use or demand exceeds supply. The northernmost Texas Panhandle region defines Region A (Figure 1) and includes 21 counties, most of which are agriculturally based. Although the region contains vast tracts of rangeland, most of the counties are intensively irrigated. Since increases in other water sectors are typically derived from the irrigation sector, decline in well capacity and increasing groundwater district regulation have reduced aquifer pumping to meet only a limited percentage of full crop evapotranspiration (ET) requirements. The target goal of most of the Region A groundwater districts is that in 50 years, 50 percent of the Ogallala groundwater should remain for future generations. This goal has become known as the 50 in 50 rule and effectively determines the allowable volume of water that can be pumped per three-year period. Previously, this goal value had been interpreted on a district wide basis, but recently it is being evaluated on a county-by-county basis.

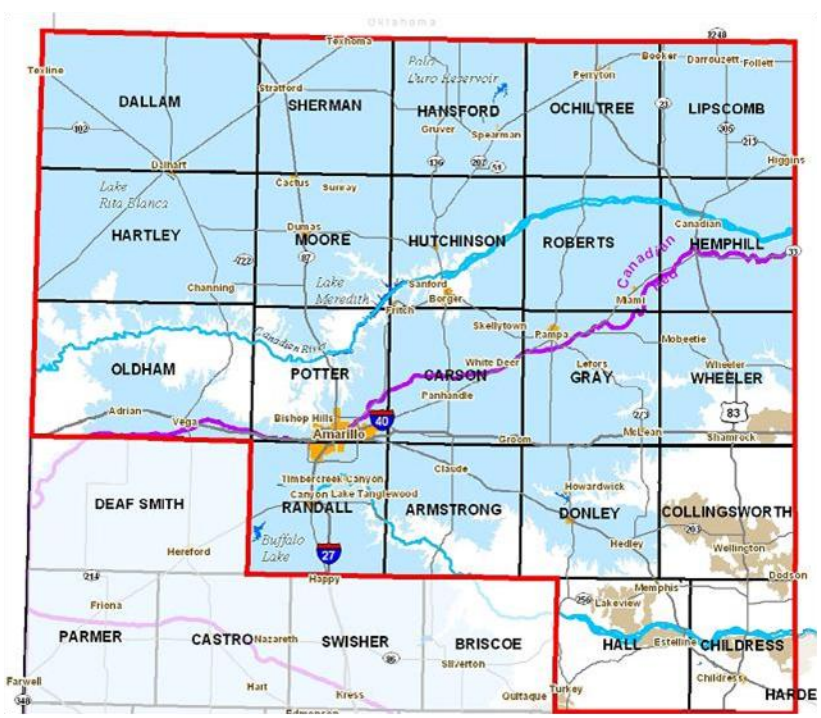

Figure 1. Twenty-one Texas Panhandle counties defined as Region A.

Thus, irrigation scheduling and timely water management using accurate reference ET and crop coefficients are important for Region A producers and crop consultants to prevent over irrigation. These data are being provided through the North Plains ET network (Marek et al. 1996). Additional conservation strategies for agricultural water withdrawals included changes in crop variety, irrigation equipment improvements, changes in crop type, implementation of conservation tillage methods, precipitation enhancement, and conversion from irrigated to dryland farming. Analysis results indicate that while water was conserved implementing some of the strategies, several would be devastating to the regional economy (Amosson et al. 2005). Assuming water savings was the principle objective, the strategy of the use of conservation tillage yielded relatively minimal water savings. The strategy of conversion of irrigated to dry land production generated large water savings, but it significantly impacted the regional economy in a negative manner. The strategies of precipitation enhancement and irrigation scheduling provided both a substantial water savings and were determined to have a positive impact on the regional economy, but do not meet the extent of the water savings needed over the 60-year horizon. Given that the groundwater supply is not projected to meet the allowable water use demands in the Region A counties of Dallam, Hartley, Moore, Sherman, and Hansford (Figure 2), measures must continue to be evaluated to reduce the anticipated irrigation water use that are feasible. The strategy of crop change previously evaluated yielded large water savings but with dramatic impact costs to the economy. Recent northern management and production levels with cotton may challenge some of the original study assumptions, particularly as acceptable levels of net profit are being realized by area producers and with reduced irrigation water use.

Research production trials (Marek and Bordovsky 2006 and Marek and Stovall 2006) and at the North Plains Research Field (36° 00' N. latitude, 101° 59' W. longitude, 3,618 elevation) near Etter, Texas indicate that cotton can be grown successfully (Table 1). Analysis conducted by Gowda et al. (2007) and Esparza et al. (2007) indicate that there are sufficient heat units available for long term cotton production within Region A. Furthermore, the previous water planning analysis did not explicitly evaluate the cotton conversion potential and its impact with updated acreages with the Texas A&M–Amarillo (TAMA) model for the entire Region A. Thus, this analysis yields the estimated values of irrigation water reduction utilizing a cotton crop conversion within all current corn producing counties within Region A.

Table 1. Six-year cotton production values at North Plains Research Field, Etter Texas (NPRF) (1999-2001 and 2004-2006).

NPRF	Average Yield	Maximum Yield	Minimum Yield	Average Micronaire	Average Uniformity
6-year Values	lbs/ac	lbs/ac	lbs/ac		
	953	2,027	426	3.47	81.09

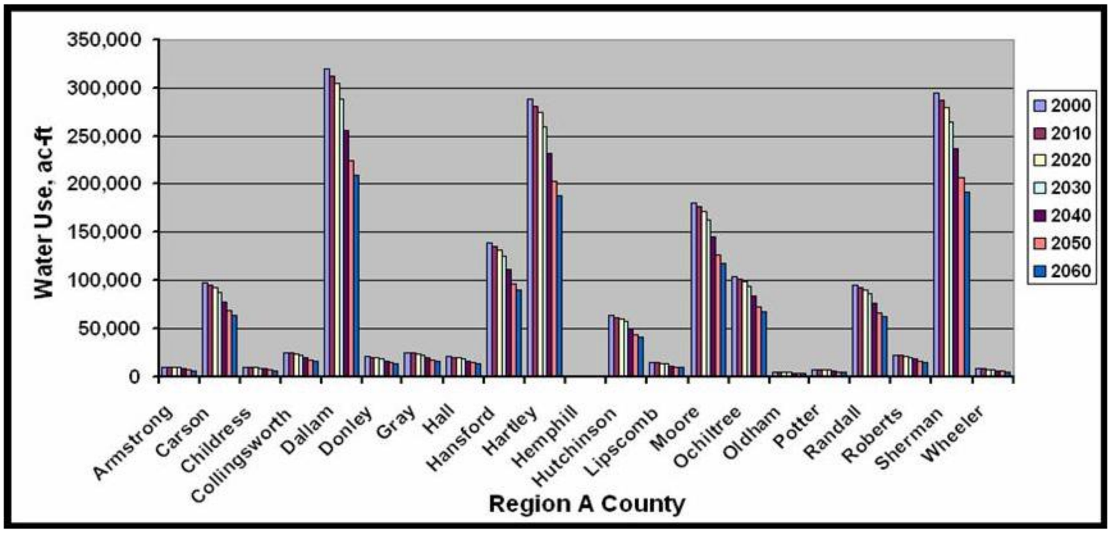

Figure 2. Estimated irrigation demand of Region A by county by decade year for 2000 through 2060 (Marek, 2004).

Methodology

Annual estimates of irrigation water use for the northern Texas Panhandle region have been computed and found to be accurate and timely for planning purposes. These estimates have been computed for a 60-year horizon beginning from year 2000 using an irrigation water use model developed for the region (Marek et al. 2004).

The approach using the TAMA model methodology is essentially one with a water balance derivation. The methodology utilizes a crop categorized, reference ET based, crop water use computation concept (Marek et al. 2003). As with most efforts of modeling, representative data per county are essential for the estimation model results to be accurate. County data are required regarding crop acreage, water use (by crop type), monthly rainfall, soil water holding capacity and crop evapotranspiration (ETc). Previous reported acreage differences and sources have been a concern regarding prior modeling efforts (Amosson et al. 1999). The latest version of the TAMA model utilize crop acreages available from the USDA-Farm Service Agency (FSA) that are based on the acreage that producers report to the FSA for their crop payment(s). The TAMA model also utilizes a term called a “grower factor” (which effectively represents the amount of crop ET pumped and includes the percent of crop ET generally applied by producers per county using all irrigation type systems and efficiencies, including conveyance losses). Additionally, the model takes into account effective rainfall within a growing season, and the soil water holding capacity per growing season. The grower factor could be synonymously labeled as a “pumpage factor”. All of these data are required on a county-by-county basis for the TAMA model. The acreages used in the model are the reported acreages of the crops planted, not the harvested values.

The TAMA model is based on the crop water use equation as follows:

$$P_T(ET_C) = IRR_C + ER + SSM_D \quad (1)$$

where:

- P_T = Grower factor which represents a percentage of the crop evapotranspiration pumped on a crop's seasonal basis (%) and includes all irrigation systems and associated efficiencies (can be more or less than 1.0 reference crop ET, ETc),
- ET_C = Crop evapotranspiration (or crop water use) for maximum production potential,
- IRR_C = Irrigation applied on a seasonal basis to a crop,
- ER = Effective rainfall computed from seasonal rainfall occurring during the crop season, and
- SSM_D = Differential seasonal soil moisture used in crop production which is extracted from the soil profile during the respective growing season.

Rearranging the equation and solving for an IRR_C yields:

$$IRR_C = ET_C(P_T) - ER - SSM_D \qquad (2)$$

The summary equation for all categorized crops grown per county is:

$$IRR_{CTY} = \sum_{1}^{n} IRRc \qquad (3)$$

where:

n = number of categorized crops of interest per county, and
IRR_{CTY} = Total quantity of irrigation volume applied (or pumped) to the crops grown within a county in a given year or season.

Similarly, the regional demand equation for the counties is:

$$IRR_{REG} = \sum_{1}^{n} IRR_{CTY} \qquad (4)$$

where:

IRR_{REG} = Total quantity of irrigation volume applied (or pumped) to crops grown within a region in a given year or crop season.

The above combination of equations does not contain applicable unit conversions and it is left to the user to ensure that unit agreement is attained between the respective equations based on unit data inputs.

In this analysis, the nominal annual amount of ETc for cotton evaluated was set at approximately half that of respective county corn ETc and the county impact was computed by changing 50% of the corn acreage to a cotton crop. Average production based ETc (estimated crop ET) for cotton at the NPRF support this nominal value. The average grower factors of the respective crops of year 2000 were maintained throughout the 60-year period computations to yield a consistent basis of impact evaluation.

Results and Discussion

This cotton crop conversion analysis was conducted to assess the potential Region A water savings as compared with prior irrigation demand estimates. The irrigation use values that were originally estimated for year 2000 assumed a slight, progressive reduction over time trend due to declining well capacity and nominal measures of conservation practices and are presented in Table 2. Irrigation was expected to decline 35% from the year 2000 basis irrigation demand over the 60-year planning horizon as producers complied with the 50 in 50 rule, as the aquifer level diminished and accounting for withdrawal increases in water use by other water use sectors (Marek et al. 2004).

Table 2. Irrigation demand estimates by decade year, 2000-2060.

Region A Counties	Irrigation Water Use by Decade Year (ac-ft)						
	2000	2010	2020	2030	2040	2050	2060
Armstrong	10,544	10,280	10,017	9,490	8,435	7,381	6,854
Carson	97,345	94,912	92,478	87,611	77,876	68,142	63,274
Childress	10,304	10,046	9,789	9,273	8,243	7,213	6,698
Collingsworth	25,607	24,967	24,327	23,046	20,486	17,925	16,645
Dallam	320,475	312,463	304,452	288,428	256,380	224,333	208,309
Donley	21,019	20,493	19,968	18,917	16,815	14,713	13,662
Gray	25,499	24,862	24,224	22,949	20,399	17,850	16,575
Hall	20,789	20,269	19,749	18,710	16,631	14,552	13,513
Hansford	138,389	134,929	131,470	124,550	110,711	96,872	89,953
Hartley	289,008	281,783	274,557	260,107	231,206	202,306	187,855
Hemphill	2,518	2,455	2,392	2,267	2,015	1,763	1,637
Hutchinson	63,208	61,628	60,048	56,887	50,567	44,246	41,085
Lipscomb	36,146	35,242	34,338	32,531	28,916	25,302	23,495
Moore	180,594	176,079	171,564	162,535	144,475	126,416	117,386
Ochiltree	104,220	101,615	99,009	93,798	83,376	72,954	67,743
Oldham	5,223	5,092	4,962	4,700	4,178	3,656	3,395
Potter	8,009	7,809	7,608	7,208	6,407	5,606	5,206
Randall	30,150	29,397	28,643	27,135	24,120	21,105	19,598
Roberts	22,890	22,318	21,746	20,601	18,312	16,023	14,879
Sherman	294,703	287,336	279,968	265,233	235,763	206,292	191,557
Wheeler	8,335	8,127	7,919	7,502	6,668	5,835	5,418
Region Totals	1,714,976	1,672,102	1,629,227	1,543,479	1,371,981	1,200,483	1,114,735

The input acreage and water use data changes of the corn to cotton conversion in this analysis are presented in Table 3. The resulting changes in irrigation demand per county per decade year are presented in Table 4. The total demand of all Region A counties result in a net reduction of pumpage amounting to about 10.45 million ac-ft as compared to the prior estimated scenario. This value is obtained by assuming the mean pumpage between decade values and summing these mean values for the years 2010 to 2060. From this volume, it is apparent that more reduction in groundwater withdrawals will be required to meet the 50 in 50 goal over the next 60-year planning horizon. This is particularly impacting if the demand versus supply balance is to be controlled on a county-by-county basis rather than by the presently interpreted groundwater district basis. (This issue is presently being discussed among the groundwater districts and the public).

With the recent federal government commitment to support ethanol programs, the likelihood of a full 50% conversion in even the five counties is unlikely and the negative impact to the Ogallala aquifer is likely to increase during the immediate interim period until such time as the volume of Ogallala water is restricted, potentially through regulation. The implications that an increased overdraft will have on future allowable volumes virtually mandates that producers reduce water use crops over the current groundwater districts' three-year assessment period scenario. Cotton, however, is currently one of the few crops that approach the net profitability of corn. With the new cotton gin in Moore County and with another recently completed in Hansford County, cotton is viewed to be an integral part of the longer-term cropping mix for Region A producers. The Moore County Gin has ginned nearly twice the design capacity (Marek and Stovall 2006) in each of the first two seasons of operation (design capacity: 50,000 bales per year; annual bales ginned: over 90,000). This clearly shows that cotton can be successfully grown within the northern Region A counties. Even with this years surge in corn production and increased commodity price, the gin's contracted design capacity (50,000 bales) was exceeded with the local production in 2007. Nonetheless, cotton conversion alone will not attain the water reduction needed to meet the 50 in 50 goal in the five counties that are currently over drafting groundwater.

Table 3. Years 2000 and 2010-2060 acreages and years 2000 and 2010 irrigation water use changes of a corn to cotton conversion scenario in Region A.

Region A Counties	Acreage, acres				Irrigation Water Use, ac-ft			
	Year 2000		Years 2010-2060		Year 2000		Year 2010*	
	FSA Corn	FSA Cotton	Conv. Corn	Conv.Cotton	Corn	Cotton	Conv. Corn	Conv.Cotton
Armstrong	732	0	366	366	1,203	0	586	375
Carson	15,966	682	7,983	8,665	24,880	688	12,129	8,526
Childress	0	5,687	0	5,687	0	5,816	0	5,671
Collingsworth	30	5,508	15	5,523	42	4,003	21	3,913
Dallam	0	15	0	83,490	243,416	13	118,666	71,711
Donley	1,216	5,303	608	5,911	1,782	4,281	869	4,653
Gray	6,268	54	3,134	3,188	9,360	49	4,563	2,808
Hall	0	11,349	0	11,349	0	9,432	0	9,197
Hansford	31,668	0	15,834	15,834	53,118	0	25,895	16,635
Hartley	131,041	2,925	65,521	68,446	202,196	2,820	98,571	64,346
Hemphill	0	0	0	0	0	0	0	0
Hutchinson	14,401	0	7,201	7,201	23,059	0	11,241	7,067
Lipscomb	8,590	0	4,295	4,295	12,284	0	5,989	3,348
Moore	83,739	0	41,870	41,870	124,085	0	60,491	37,388
Ochiltree	15,626	0	7,813	7,813	25,076	0	12,225	7,712
Oldham	0	30	0	30	0	36	0	35
Potter	347	225	174	399	593	256	289	442
Randall	1,774	2,418	887	3,305	3,134	2,818	1,528	3,756
Roberts	1,971	0	986	986	3,111	0	1,517	932
Sherman	91,741	399	45,871	46,270	154,387	444	75,263	50,208
Wheeler	375	2,264	188	2,452	571	2,147	278	2,267
Totals	405,485	36,859	202,743	323,076				

* Decade years 2020-2060 reduce accordingly within the TAMA models water availability decline assumptions.

Table 4. Region A irrigation demand estimates per county per decade year with a 50% corn to cotton acreage conversion (2000-2060).

Region A Counties	"50% Conversion Scenario" Irrigation Water Use by Decade Year (ac-ft)						
	2000	2010	2020	2030	2040	2050	2060
Armstrong	10,544	10,069	9,811	9,294	8,262	7,229	6,713
Carson	97,345	90,637	88,313	83,665	74,369	65,073	60,425
Childress	10,304	10,046	9,789	9,273	8,243	7,213	6,698
Collingsworth	25,607	24,957	24,317	23,037	20,478	17,918	16,638
Dallam	320,475	265,496	258,689	245,074	217,843	190,613	176,998
Donley	21,019	20,103	19,588	18,557	16,495	14,433	13,402
Gray	25,499	23,059	22,467	21,285	18,920	16,555	15,372
Hall	20,789	20,269	19,749	18,710	16,631	14,552	13,513
Hansford	138,389	125,670	122,448	116,003	103,114	90,225	83,780
Hartley	289,008	244,808	238,531	225,976	200,868	175,759	163,205
Hemphill	2,518	2,455	2,392	2,267	2,015	1,763	1,637
Hutchinson	63,208	57,454	55,980	53,034	47,141	41,249	38,302
Lipscomb	36,146	32,601	31,765	30,093	26,749	23,406	21,734
Moore	180,594	152,975	149,053	141,208	125,518	109,829	101,984
Ochiltree	104,220	97,102	94,613	89,633	79,674	69,714	64,735
Oldham	5,223	5,092	4,962	4,700	4,178	3,656	3,395
Potter	8,009	7,712	7,514	7,119	6,328	5,537	5,141
Randall	30,150	28,877	28,136	26,655	23,694	20,732	19,251
Roberts	22,890	21,733	21,176	20,062	17,833	15,603	14,489
Sherman	294,703	261,847	255,133	241,705	214,849	187,993	174,565
Wheeler	8,335	8,022	7,816	7,405	6,582	5,759	5,348
Totals	1,714,976	1,510,986	1,472,243	1,394,756	1,239,783	1,084,810	1,007,324

Conclusions

Results of this analysis indicate agreement with similar crop type conversion analysis by Gaskins (2004) and Amosson (2005) in that significant (50%) corn to cotton conversion would positively impact groundwater conservation of the Ogallala aquifer over the 60-year planning horizon. Implementing this level of conversion will, however, require impacting measures to be taken within the region, potentially even through irrigation volume pumping restrictions. The water use savings estimate using the TAMA model in this analysis totaled 10.45 million ac-ft of irrigation water savings over the next 60 years, with acreage conversion beginning in 2010. This computes to approximately a 9.6% reduction in expected groundwater withdrawal. Currently the estimated, average irrigation withdrawal rate for Region A exceeds 1.46 million ac-ft per year. The potential water savings are thus significant and this crop conversion strategy should be further evaluated for updated economic and socioeconomic impacts.

Corn to cotton conversion changes in Dallam County (the most northwestern county of Region A) and adjoining counties should also be critically evaluated in terms of potential production failures. The probability of attaining adequate cotton heat units in successive years and not having consecutive year failures based on early season frosts are essential to implementing a feasible conversion scenario and sustaining profitability for regional producers.

References

Amosson, S., T. Marek, L. New, B. Stewart, and F. Bretz. (1999). “Estimated use for irrigation in Region A.” Contract Report to Freese and Nichols, Inc. for the Panhandle Water Planning Group-Panhandle Regional Planning Commission, Texas A&M University Agricultural Research and Extension Center, Amarillo, Texas. (March 15). 7 pp.

Amosson, S., L. Almas, F. Bretz, D. Gaskins, B. Guerrero, D. Jones, T. Marek, L. New, and N. Simpson. (2005). “Water management strategies for reducing irrigation demands in Region A.” Technical Report to Agricultural Sub-Committee-Panhandle Water Planning Group. Texas A&M University Agricultural Research and Extension Center, Amarillo, Texas. (January). 79 pp.

Esparza, A., P. Gowda, R. Baumhardt, T. Marek, and T. Howell. (2007). “Heat unit availability for cotton production in the Ogallala aquifer region of the United States.” *Journal of Cotton Science.* 11:110-117.

Freese and Nichols, Inc. (2001). “Regional water plan for the Panhandle Water Planning Area.” Contract Report to Freese and Nichols, Inc. for the Panhandle Water Planning Group-Panhandle Regional Planning Commission, Texas A&M University Agricultural Research and Extension Center, Amarillo, Texas. (January 31).

Freese and Nichols, Inc. (2006). “Regional water plan for the Panhandle Water Planning Area.” Contract Report to Freese and Nichols, Inc. for the Panhandle Water Planning Group-Panhandle Regional Planning Commission, Texas A&M University Agricultural Research and Extension Center, Amarillo, Texas. <http://www.panhandlewater.org> (January 14, 2008).

Gaskins. D. (2004). Change in crop type. “Water management strategies for reducing irrigation demands in Region A.” Contract Report to Agricultural Sub-Committee-Panhandle Water Planning Group. Texas A&M University Agricultural Research and Extension Center, Amarillo, Texas. 7 pp.

Gowda, P., R. Baumhardt, A. Esparza, T. Marek, and T. Howell. (2007). “Suitability of cotton as an alternative crop in the Ogallala aquifer region.” *Agronomy Journal* 99:1397-1403.

Marek, T., T. Howell, L. New, D. Dusek, and G. Michels. (1996). “Texas North Plains PET Network.” *Proceedings of the 1996 ASAE International Conference on Evapotranspiration and Irrigation Scheduling*, San Antonio, Texas. (November 3-6).

Marek, T, S. Amosson, L. New, F. Bretz, B. Stewart, and J. Sweeten. (2000). “Irrigation water demand estimates for the Texas Panhandle (Region A).” *Proceedings of the ASCE International Watershed Management 2000 Symposium and Conference,* Colorado State University, Ft. Collins, Colorado. (June 20-24).

Marek, T., S. Amosson, L New, F. Bretz, and L. Almas. (2003). “Region A Task 2 Report: Agricultural Water Demands Projections.” Technical Report to Agricultural Sub-Committee-Panhandle Water Planning Group. Texas A&M University Agricultural Research and Extension Center, Amarillo, Texas. (August 27). 31 pp.

Marek, T., S. Amosson, R. Muttiah, L. Almas, L. New, T. Howell, F. Bretz, B. Guerrero, and N. Simpson. (2004). “Development of an agricultural irrigation water use estimating methodology.” Contract Report to Texas Water Development Board. Texas A&M University Agricultural Research and Extension Center, Amarillo, Texas. (October). 110 pp.

Marek, T. and D. Bordovsky. (2006). “Performance of the ten cotton varieties in the Northern High Plains.” *Texas Journal of Agricultural and Natural Resources* 19:48-61.

Marek, T. and L. Stovall. (2006). “Cotton production in the Northern Texas High Plains”. *Proceedings of the 2006 North Plains Research Field Ag Day.* Texas A&M University Agricultural Research and Extension Center, Amarillo, Texas. AREC No. 06-32.